US009746017B2

(12) United States Patent
Ota et al.

(10) Patent No.: US 9,746,017 B2
(45) Date of Patent: Aug. 29, 2017

(54) FASTENER INCLUDING A WIRELESS MODULE AND A WIRELESS DEVICE ATTACHABLE TO THE SAME

(71) Applicant: **KABUSHIKI KAISHA TOSHIBA**, Tokyo (JP)

(72) Inventors: **Hiroshi Ota**, Misato Saitama (JP); **Daigo Suzuki**, Kawasaki Kanagawa (JP); **Yasuhiro Fukuju**, Yokohama Kanagawa (JP)

(73) Assignee: **Kabushiki Kaisha Toshiba**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/062,005**

(22) Filed: **Mar. 4, 2016**

(65) **Prior Publication Data**

US 2017/0082132 A1 Mar. 23, 2017

Related U.S. Application Data

(60) Provisional application No. 62/221,838, filed on Sep. 22, 2015.

(51) **Int. Cl.**

G08B 1/08	(2006.01)
F16B 35/00	(2006.01)
G01P 15/18	(2013.01)
G08B 5/00	(2006.01)
G01R 33/02	(2006.01)
G01C 19/56	(2012.01)
G08B 25/10	(2006.01)

(52) **U.S. Cl.**

CPC ***F16B 35/00*** (2013.01); ***G01C 19/56*** (2013.01); ***G01P 15/18*** (2013.01); ***G01R 33/0206*** (2013.01); ***G08B 5/00*** (2013.01); *G08B 25/10* (2013.01)

(58) **Field of Classification Search**

CPC F16B 35/00; F16B 35/06; F16B 41/005; F16B 41/007; F16B 31/025

USPC 340/539.1, 665, 671, 672, 686.1, 686.3; 73/760, 761

See application file for complete search history.

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Primary Examiner — Toan N Pham

(74) *Attorney, Agent, or Firm* — Patterson & Sheridan, LLP

(57) **ABSTRACT**

A fastener having threads includes a main body including a head portion and a thread portion having the threads, a sensor mounted on the main body and configured to detect orientation of the fastener, and a wireless module mounted on the main body and configured to transmit data indicating the detected orientation through a wireless signal.

20 Claims, 8 Drawing Sheets

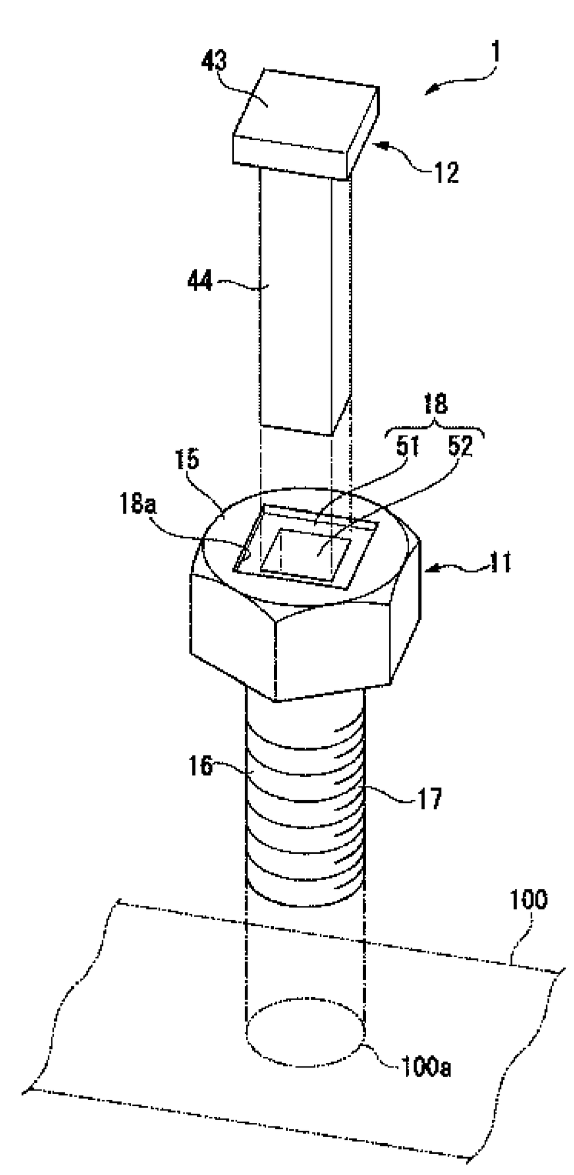

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FIG. 1

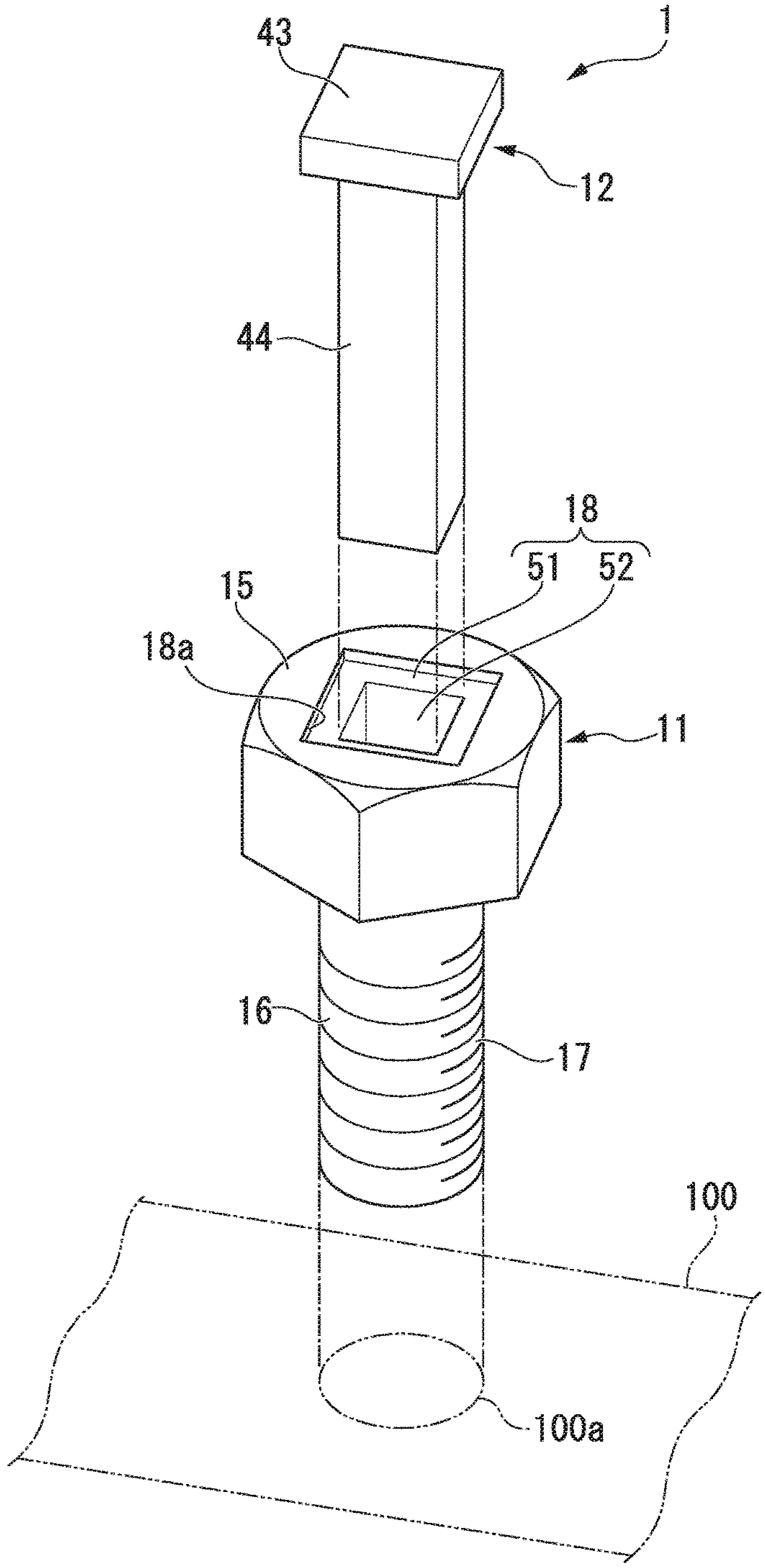


FIG. 2

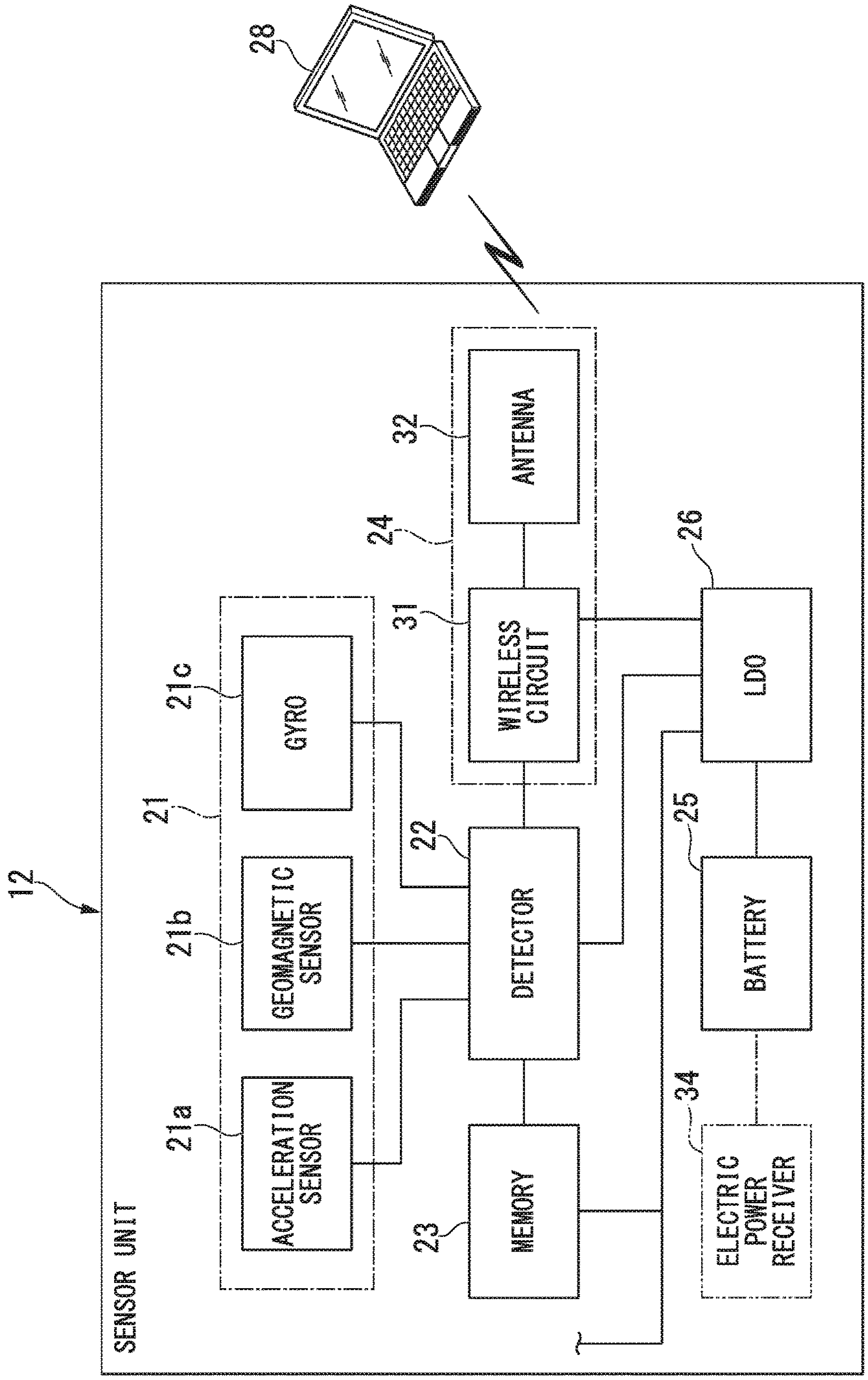
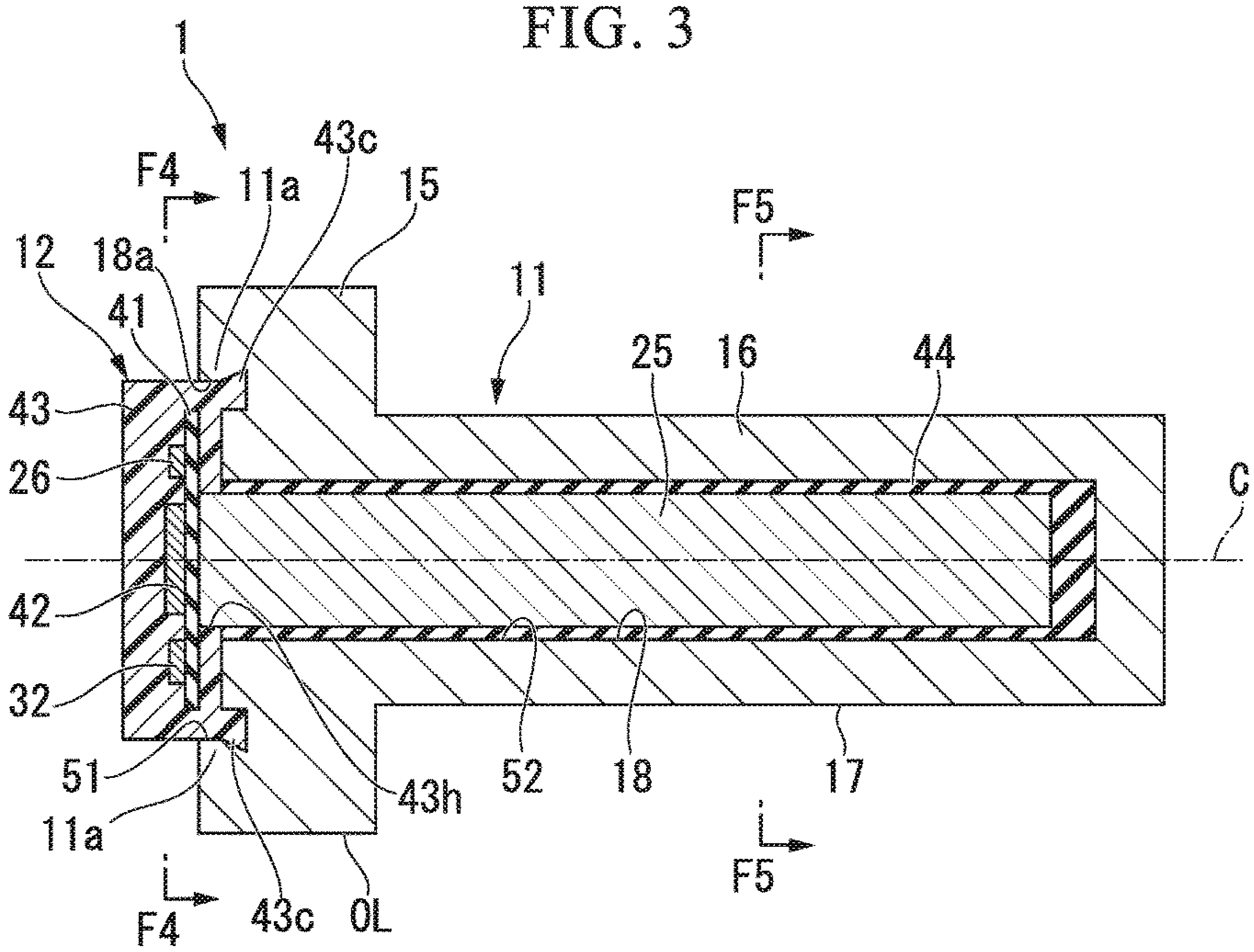

12
SENSOR UNIT
21
21a
ACCELERATION SENSOR
21b
GEOMAGNETIC SENSOR
21c
GYRO
22
DETECTOR
23
MEMORY
24
31
WIRELESS CIRCUIT
32
ANTENNA
26
LDO
25
BATTERY
34
ELECTRIC POWER RECEIVER
28

FIG. 3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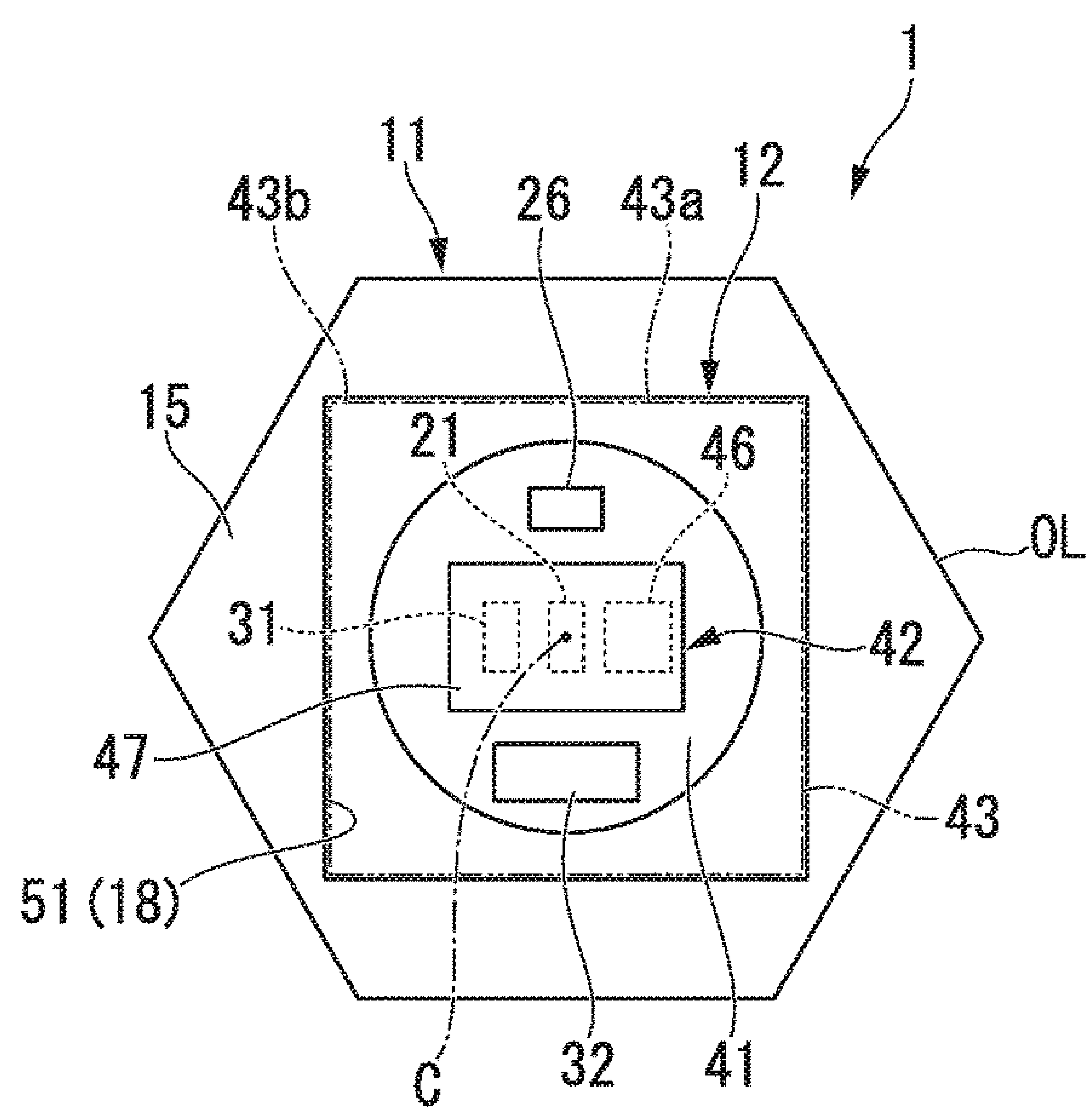
OL

FIG. 4


1
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12
43b
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42
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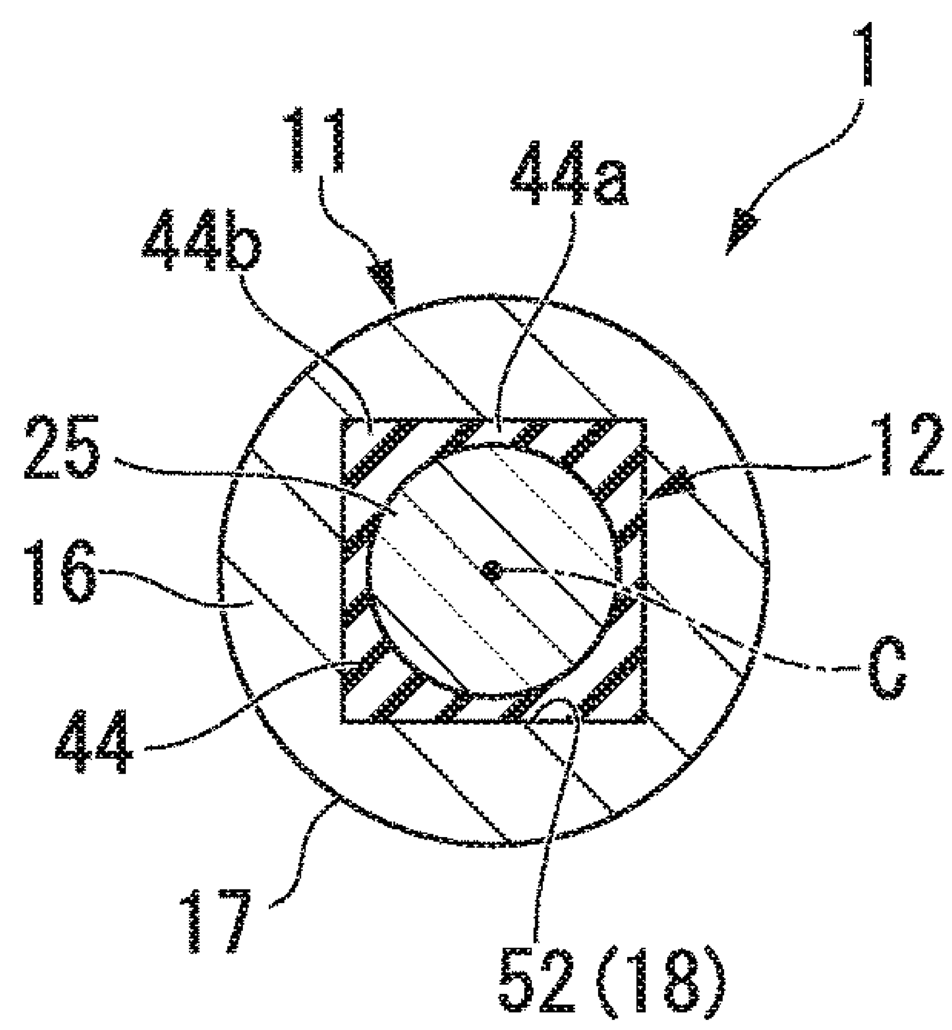
47
43
51 (18)
C
32
41

FIG. 5



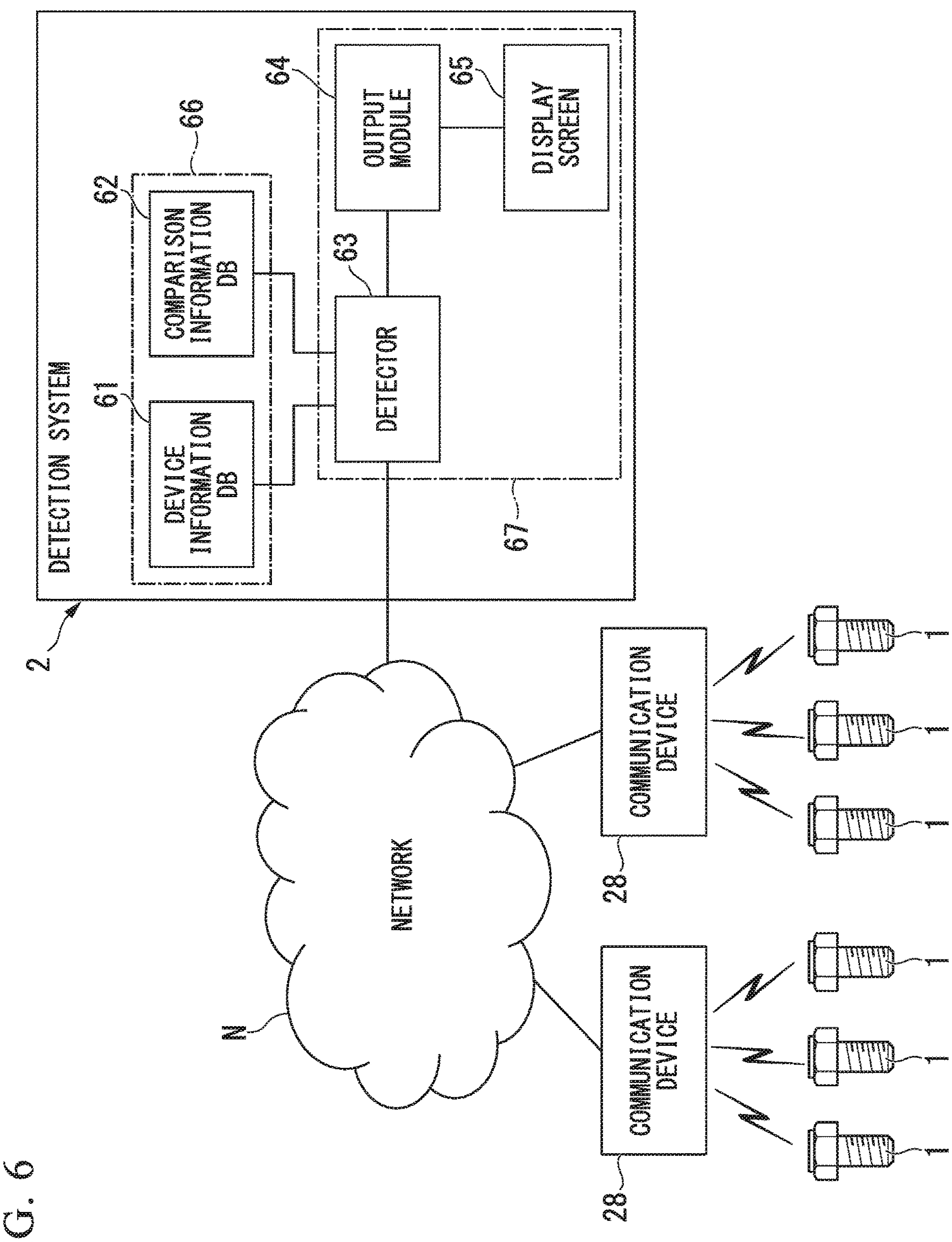

DETECTION SYSTEM
DEVICE INFORMATION DB
COMPARISON INFORMATION DB
DETECTOR
OUTPUT MODULE
DISPLAY SCREEN
NETWORK
COMMUNICATION DEVICE
COMMUNICATION DEVICE
2
61
62
63
64
65
66
67
N
28
28
1
1
1
1
1
1

FIG. 6

FIG. 7

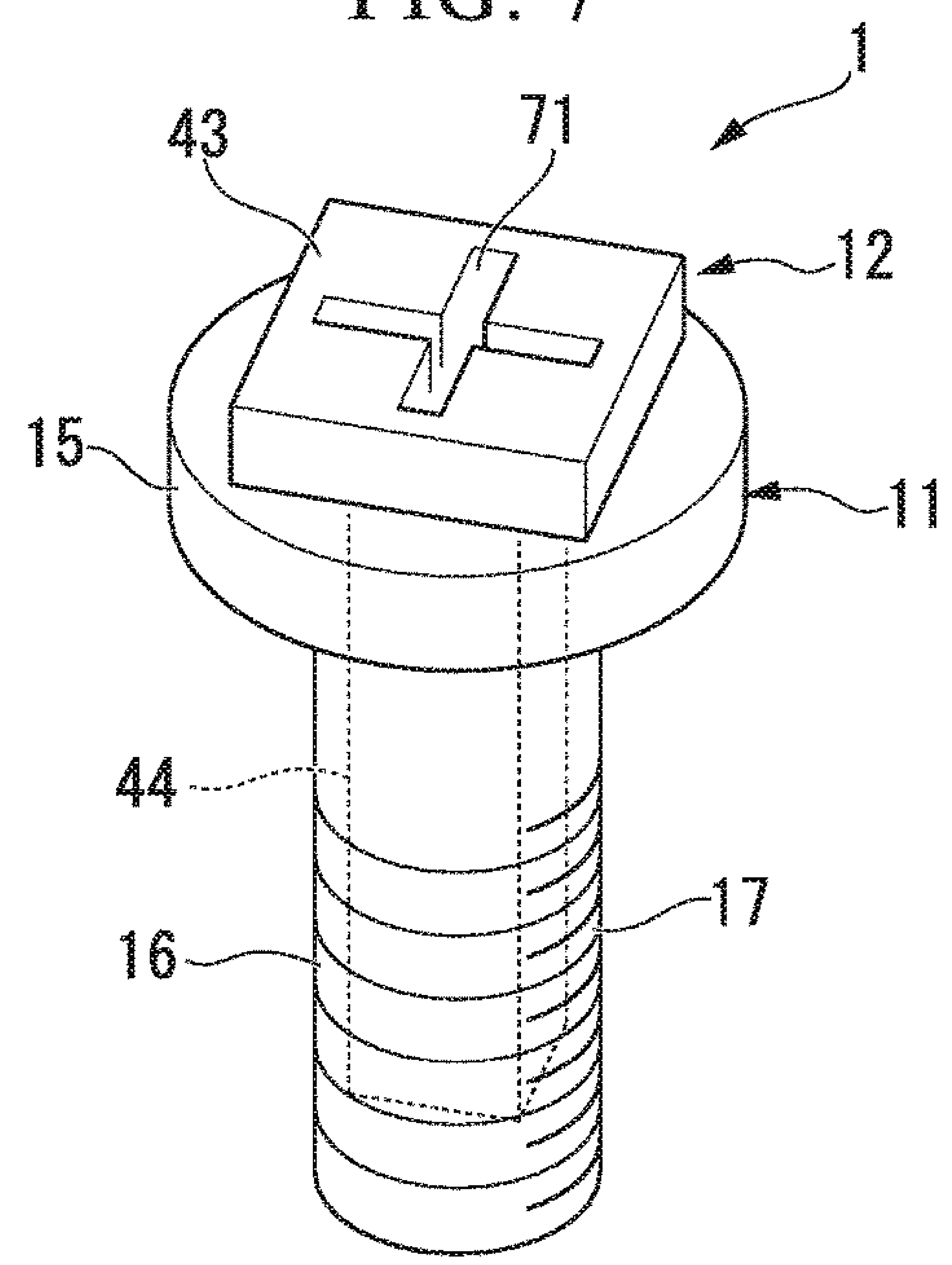


FIG. 8

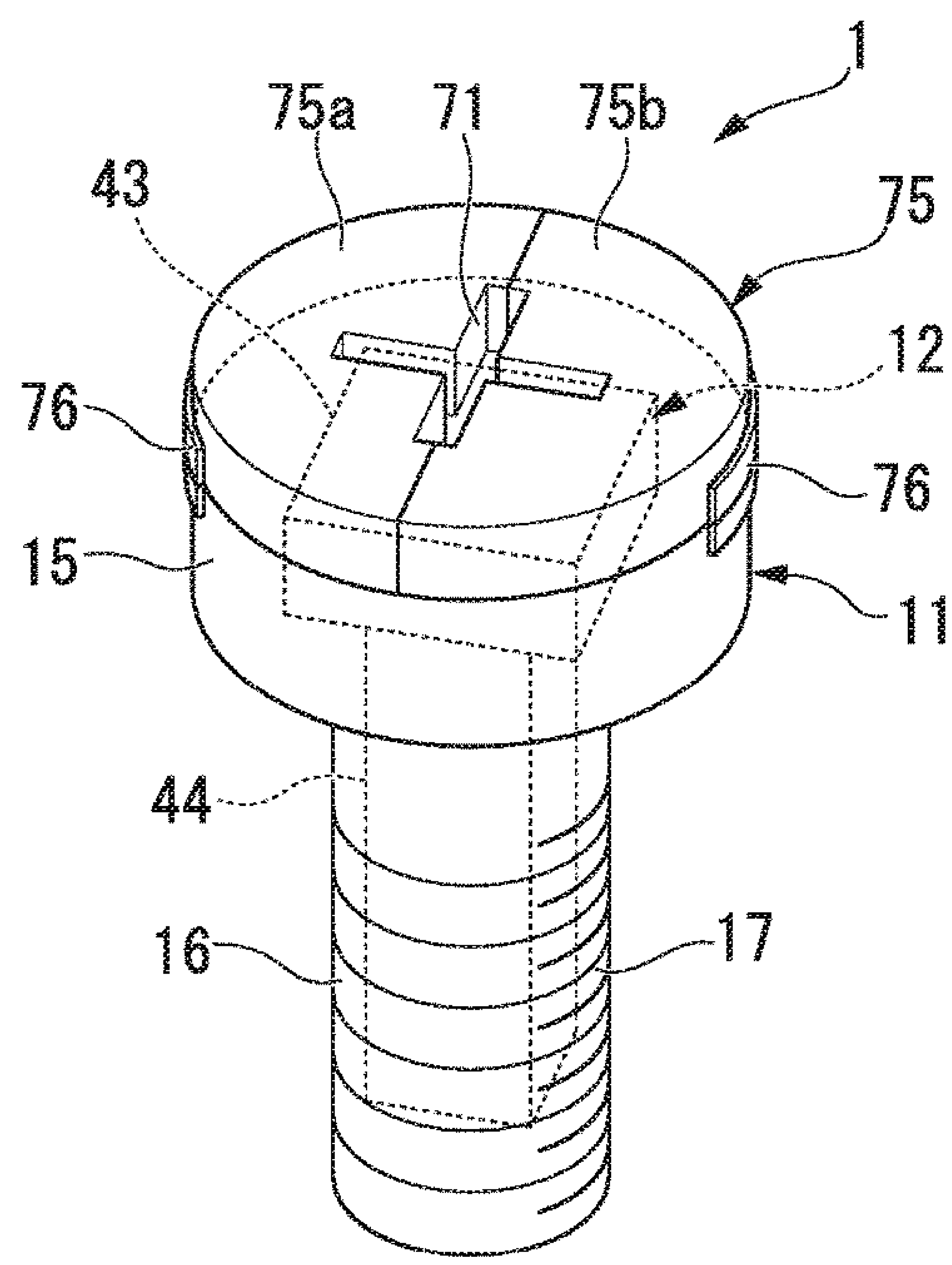
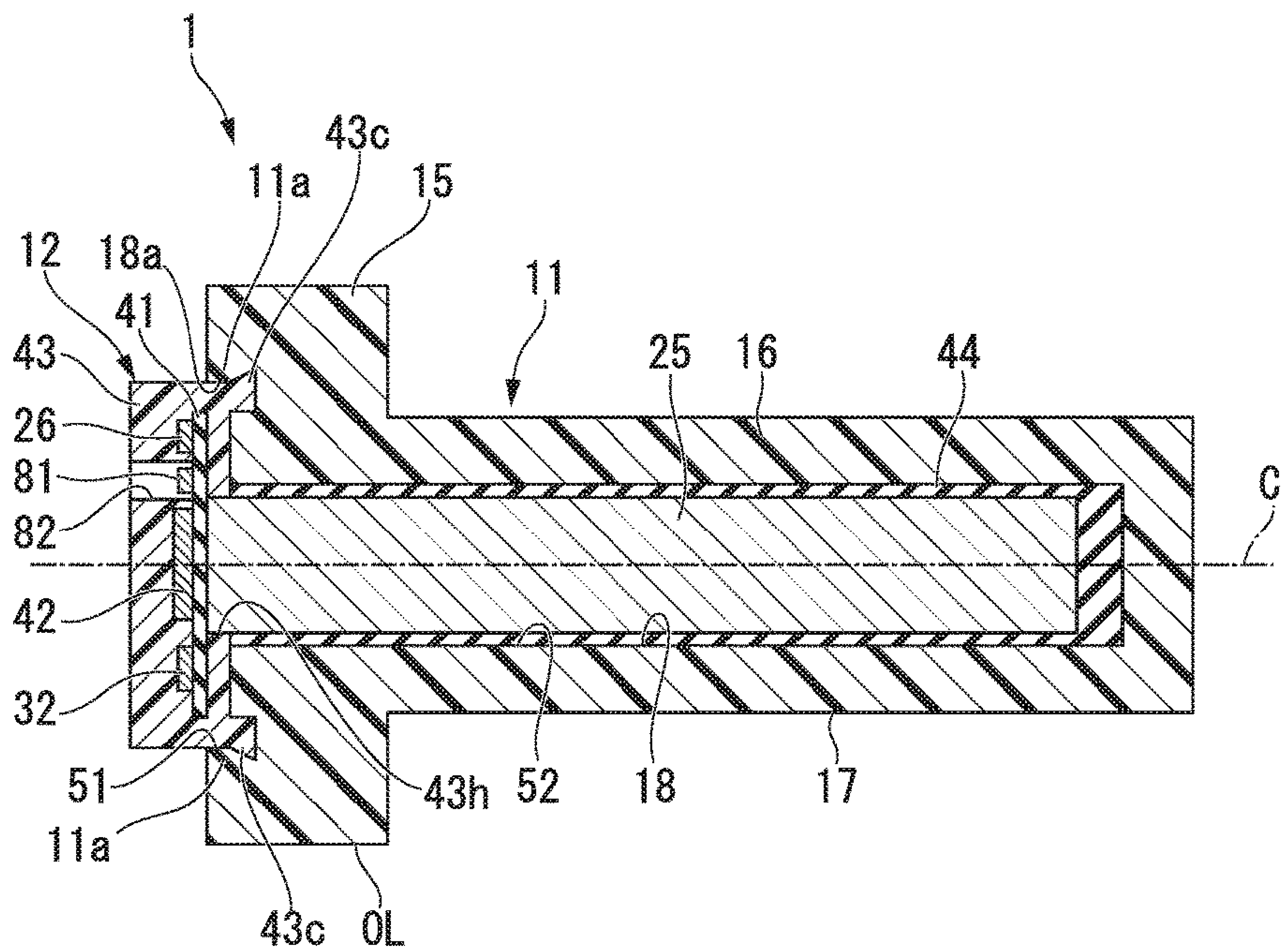


FIG. 9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18
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11a
43c
OL

FIG. 10

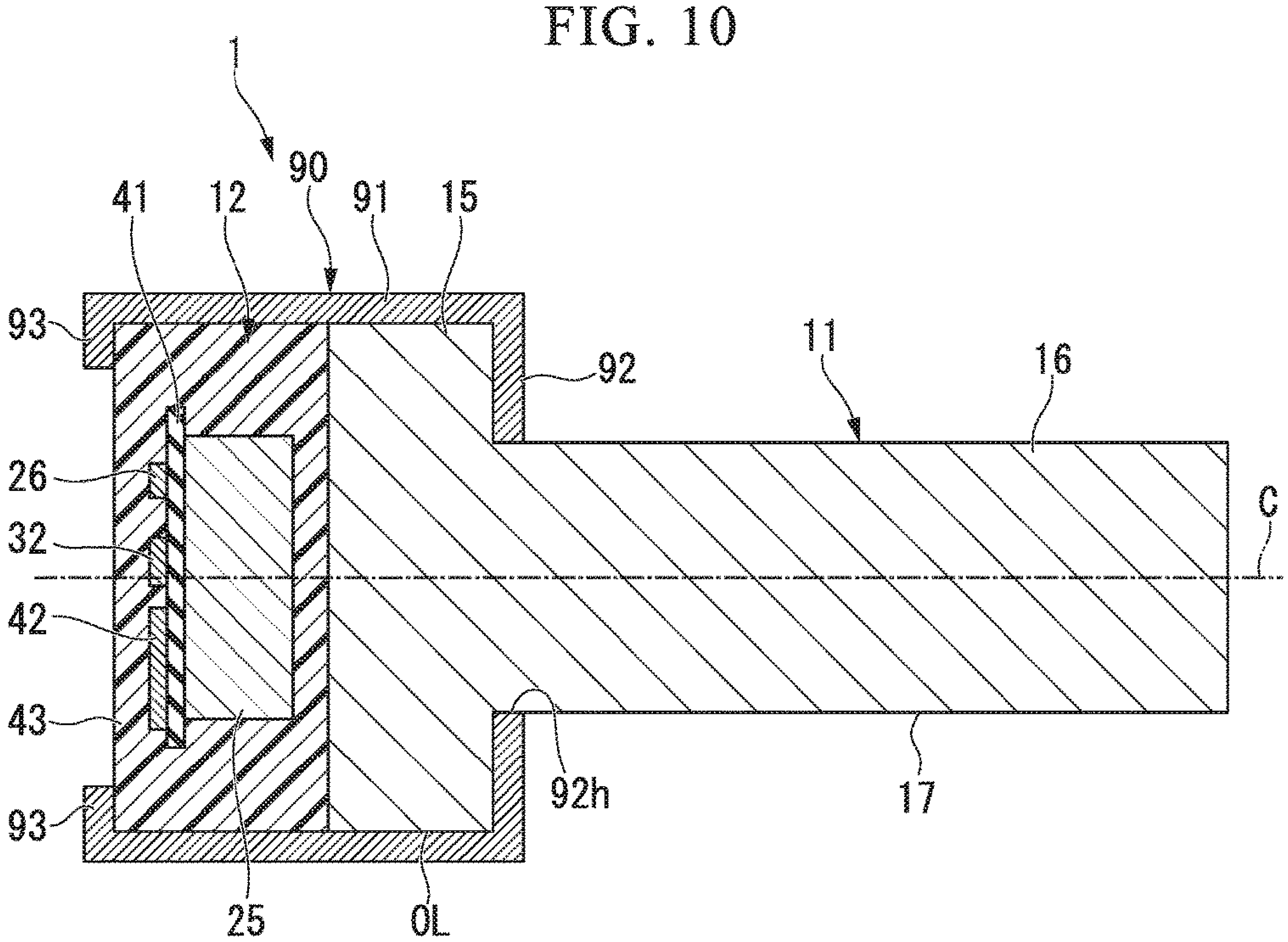
1
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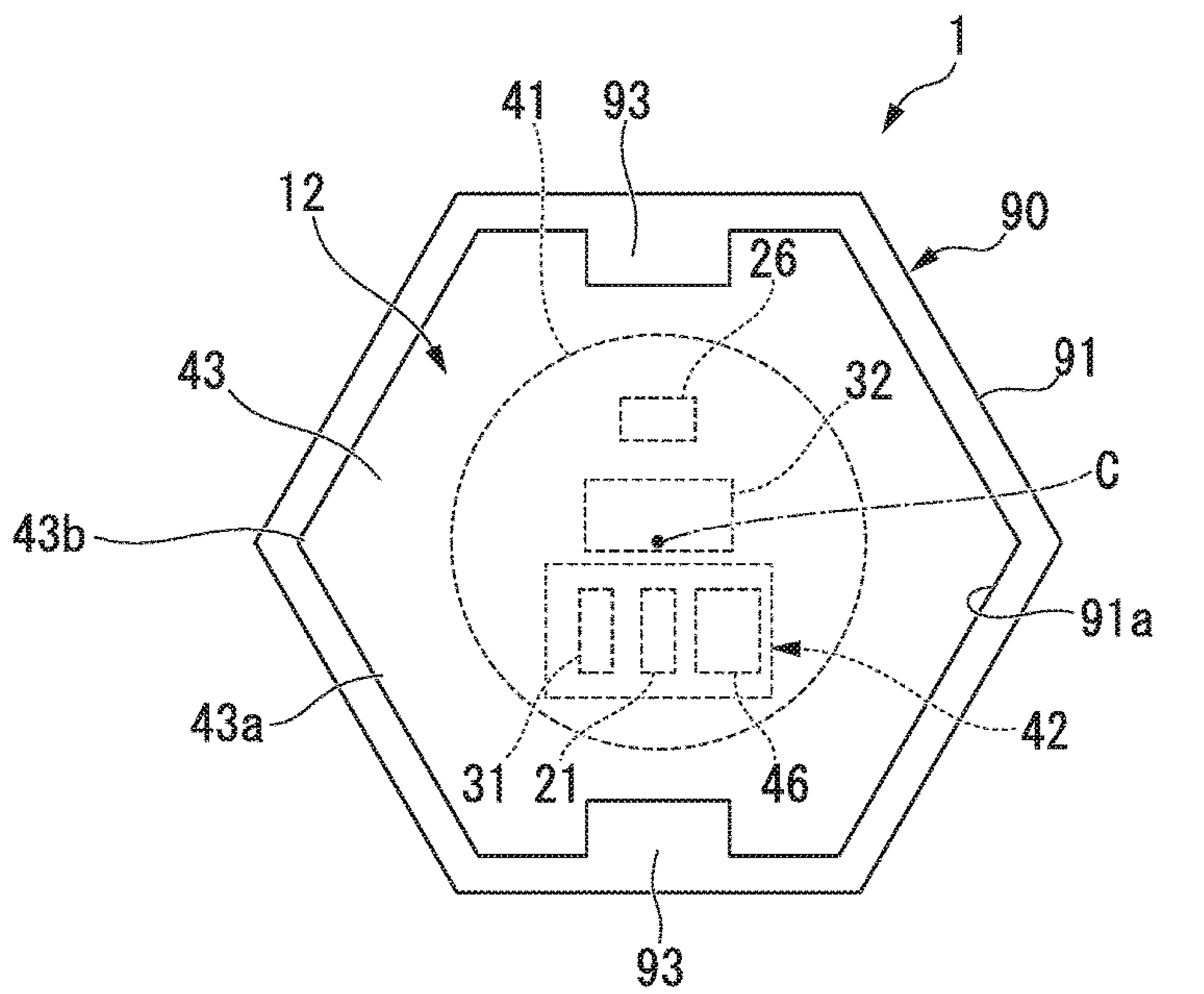
FIG. 11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43b
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43a
42
31
21
46
93

FASTENER INCLUDING A WIRELESS MODULE AND A WIRELESS DEVICE ATTACHABLE TO THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from U.S. Provisional Patent Application No. 62/221,838, filed on Sep. 22, 2015, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a fastener, in particular, a fastener including a wireless module.

BACKGROUND

An apparatus for measuring axial force on a bolt, using a strain gauge set inside the bolt is known.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially-exploded perspective view of a fastener including a wireless device according to a first embodiment.

FIG. **2** is a block diagram of a system configuration of the wireless device according to the first embodiment.

FIG. **3** is a cross-section of the wireless device according to the first embodiment.

FIG. **4** is a cross-section of the wireless device shown in FIG. **3** taken along a line segment F**4**-F**4** in FIG. **3**.

FIG. **5** is a cross-section of the wireless device shown in FIG. **3** taken along a line segment F**5**-F**5** in FIG. **3**.

FIG. **6** is a block diagram of a system configuration of a detection system according to the first embodiment.

FIG. **7** is a perspective view of a fastener including a wireless device according to a first modification example.

FIG. **8** is a perspective view of a fastener including a wireless device according to a second modification example.

FIG. **9** is a perspective view of a fastener including a wireless device according to a third modification example.

FIG. **10** is a cross-sectional diagram of a fastener including a wireless device according to a second embodiment.

FIG. **11** is a plan view of the fastener including the wireless device according to the second embodiment.

DETAILED DESCRIPTION

According to an embodiment, a fastener having threads includes a main body including a head portion and a thread portion having the threads, a sensor mounted on the main body and configured to detect orientation of the fastener, and a wireless module mounted on the main body and configured to transmit data indicating the detected orientation through a wireless signal.

Embodiments of a fastener including and a detection system are described below with reference to the drawings. In the description below, elements having the same or similar functions are described with the same reference symbol, and duplicate descriptions thereof might be omitted.

First Embodiment

A fastener including a wireless device (module) **1** and a detection system (center) **2** according to a first embodiment are described with reference to FIG. **1** through FIG. **6**.

[1. Wireless Device]

FIG. **1** is a perspective diagram of an overall configuration of a fastener including the wireless device **1**.

The wireless device **1** is an example of a "wireless apparatus", a "communication unit", and an "electronic apparatus". As illustrated in FIG. **1**, the fastener (e.g., screw and bolt) includes a main body **11**, and the wireless device **1** includes a sensor unit **12** that is mountable to the main body **11**.

The main body **11** of the fastener (hereinafter, fastener **11**) is, for example, a metallic bolt (e.g., a hex head bolt). The fastener **11** includes a head **15** and a thread body **16**. The head **15** is formed in a polygonal shape (e.g., hexagonal shape). The thread body **16** is formed in a cylindrical shape thinner than the head **15**, and is connected (i.e., fixed) to the head **15**. An external peripheral surface of the thread body **16** includes multiple screw threads (typically, helical threads). The thread body **16** is inserted into a screw hole (i.e., threaded hole) **100***a* of a fixation object (i.e., object to be fixed) **100**, and engaged with the fixation object **100**. It is possible to utilize the fastener **11** of the present embodiment in a variety of fields, for example shelves, air conditioners, bridges, building, railways, vehicles, and the like.

As illustrated in FIG. **1**, a mounting hole (i.e., housing) **18** for mounting the sensor unit **12** is formed in the fastener **11**. A mounting structure of the sensor unit **12** to the fastener **11** is described below in detail.

[1. Sensor Unit]

FIG. **2** is a block diagram of a system configuration of the sensor unit **12**. As illustrated in FIG. **2**, the sensor unit **12** includes a sensor (e.g., sensor module) **21**, a detector **22**, a memory **23**, a wireless module **24** a battery **25**, and an electric power supply component **26**.

The sensor **21** includes an acceleration sensor **21***a*, a geomagnetic sensor **21***b*, and a gyro **21***c*.

The acceleration sensor **21***a* is an inertial sensor that measures acceleration, and can detect a gravitational force direction. The acceleration sensor **21***a* of the present embodiment is, for example, a three-axis acceleration sensor. That is, the acceleration sensor **21***a* measures acceleration in each of three substantially mutually orthogonal directions: an X-axis direction, a Y-axis direction, and a Z-axis direction. The acceleration sensor **21***a* outputs acceleration measurement results in each of the X-axis direction, the Y-axis direction, and the Z-axis direction to a detector **22** described below.

The geomagnetic sensor **21***b* is a sensor that measures geomagnetism, and can detect a magnetic flux direction. The geomagnetic sensor **21***b* of the present embodiment is, for example, a three-axis geomagnetic sensor. That is, the geomagnetic sensor **21***b* measures geomagnetism in each of three substantially mutually orthogonal directions: an X-axis direction, a Y-axis direction, and a Z-axis direction. The geomagnetic sensor **21***b* outputs geomagnetism measurement results in each of the X-direction, the Y-direction, and the Z-direction to the detector **22**.

The gyro (i.e., gyro sensor) **21***c* is an example of a "vibration detection sensor", and can detect vibrations imparted to the fastener **11**. The gyro **21***c* of the present embodiment is, for example, a three-axis gyro. That is, the gyro **21***c* measures vibrations in each of three substantially mutually orthogonal directions: an X-axis direction, a Y-axis direction, and a Z-axis direction. The gyro **21***c* outputs vibration measurement results in each of the X-direction, the Y-direction, and the Z-direction to the detector **22**.

The sensor **21** of the present embodiment is thus a nine-axis sensor that is capable of measuring acceleration in three axes, geomagnetism in three axes, and vibration in three axes. In the present embodiment, the sensor **21** is coupled with the fastener **11** as a portion of the sensor unit **12**. In other words, the sensor **21** is fixed to the fastener **11**. In the present embodiment, "a sensor is fixed to a fastener" includes a case where the sensor is fixed to the fastener with another member (e.g., protection member or attaching member) interposed between the sensor and the fastener, in addition to a case the sensor is directly fixed to the fastener. When the orientation of the fastener **11** changes, the orientation of the sensor **21** changes corresponding to the changes in the orientation of the fastener **11**. For example, when the fastener **11** rotates, the sensor **21** rotates integrally with the fastener **11**. The sensor **21** thus generates outputs as detection results based on changes in the orientation of the fastener **11**. For example, as one example of the detection results, the sensor **21** outputs values based on changes in the orientation of the fastener **11**. As one example of the detection results, the sensor **21** may generate outputs which represent changes in the orientation of the fastener **11**.

In the present disclosure, when discussing a "value", for example a "value based on a change" as described above, the "value" is not limited to a measured value, and further, is not limited to a numerical value. "Value" may be an indicator which indicates an attribute, for example High/Low.

Further, the sensor **21** may also output other detection results instead of those described above. For example, the sensor **21** may also output results of processes such as corrections, adjustments, screenings, or the like performed on measured values from the acceleration sensor **21***a*, the geomagnetic sensor **21***b*, or the gyro **21***c*. That is, in the present disclosure, a "detection result (or measurement result)" may also be obtained by performing a computation process, a determination process, or the like defined in advance on a measured value. For example, the sensor **21** may also output information that indicates which of multiple predefined partitions a measured value is included. For example, the sensor **21** may output identical values when changes in the orientation of the fastener **11** are minute (e.g., rotation is equal to or less than 0.5°).

Further, in the present disclosure "changes in the orientation of the fastener" means changes equal to or greater than the size of the smallest unit capable of being resolved by the sensor **21** relating to the orientation of the fastener **11**. That is, all changes, even minute changes, equal to or greater than the size of the smallest unit capable of being resolved by the sensor **21** correspond to "changes in the orientation of the fastener".

Further, in the present disclosure "changes in the orientation of the fastener" includes rotation (e.g., looseness) of the fastener **11** with respect to the fixation object **100**, changes in inclination of a center axis C of the fastener **11** (refer to FIG. **3**), and the like. "Rotation of the fastener with respect to the fixation object" as used here means rotation around the center axis C of the fastener **11** (i.e., a center axis of the thread body **16**). Further, "changes in inclination of the center axis of the fastener" includes changes in inclination of the fastener **11** with respect to the fixation object **100**, and changes in inclination of the fastener **11** due to inclination of the fixation object **100**.

In the present embodiment, when the fastener **11** rotates with respect to the fixation object **100** (i.e., for cases where the fastener **11** is getting loose), the orientation of the acceleration sensor **21***a* changes. When the orientation of the acceleration sensor **21***a* changes, the direction of the gravitational force detected by the acceleration sensor **21***a* changes. The acceleration sensor **21***a* thus outputs different values corresponding to rotation of the fastener **11**, for example.

Further, when the fastener **11** rotates with respect to the fixation object **100** (i.e., for cases where the fastener **11** gets loose), the orientation of the geomagnetic sensor **21***b* changes. When the orientation of the geomagnetic sensor **21***b* changes, the magnetic flux direction of the earth detected by the geomagnetic sensor **21***b* changes. The geomagnetic sensor **21***b* thus outputs different values corresponding to rotation of the fastener **11**, for example.

In addition, in the present embodiment, the inclination of the acceleration sensor **21***a* changes when the inclination of the center axis C of the fastener **11** changes. When the inclination of the acceleration sensor **21***a* changes, the direction of the gravitational force detected by the acceleration sensor **21***a* changes. The acceleration sensor **21***a* thus outputs different values corresponding to changes in the inclination of the center axis C of the fastener **11**, for example.

Further, when the inclination of the center axis C of the fastener **1** changes, the inclination of the geomagnetic sensor **21***b* changes. When the inclination of the geomagnetic sensor **21***b* changes, the magnetic flus direction of the earth detected by the geomagnetic sensor **21***b* changed. The geomagnetic sensor **21***b* thus outputs different values corresponding to changes in the inclination of the center axis C of the fastener **11**, for example.

In addition, in the present embodiment, when vibrations act on the fastener **11**, the gyro **21***c* outputs different values corresponding to the size of vibrations, for example.

The memory **23** and the detector **22** are described next. The memory **23** is a semiconductor memory component included in a Micro Controller Unit (MCU) **46** described below, for example. The memory **23** is a non-volatile memory, for example. The memory **23** receives output from the sensor **21** through the detector **22**, for example.

In detail, the wireless device **1** is initialized when the fastener **11** is mounted to the fixation object **100**, for example. The memory **23** receives output from the sensor **21** when the wireless device **1** is initialized. The memory **23** stores the output from the sensor **21** at initialization as an initial state value (i.e., zero correction value). The detector **22**, described below, can thus set a zero value based on the value stored in the memory **23**. Here, initialization of the wireless device **1** may also be performed by striking the wireless device **1** to input a shock to the wireless device **1**, or the like, after the fastener **11** is mounted to the fixation object **100**. Alternatively, the initialization may be performed by wireless communication from an external apparatus **28** through a wireless circuit **31** and an antenna **32** described below.

Further, at least one standard value (e.g., multiple standard values) for determining changes in the orientation of the fastener **11** (e.g., degrees of the orientation change) is stored in the memory **23**. The standard values are one example of "values set in advance". The standard values may be set, for example, for each of the three axes of acceleration and the three axes of geomagnetism.

In detail, at least one standard value (e.g., multiple standard values) for determining the degree of rotation (e.g., degree of looseness) of the fastener **11** with respect to the fixation object **100** is stored in the memory **23**. The standard values include, for example, values of changes in the three axes of acceleration, values of changes in the three axes of geomagnetism, and the like for cases of predefined angles of rotation of the fastener **11** with respect to the fixation object **100** (e.g., 10 degrees, 30 degrees, 90 degrees, one rotation, three rotations).

Further, at least one standard value (e.g., multiple standard values) for determining the degree of changes in inclination of the center axis C of the fastener **11** is stored in the memory **23**. The standard values include, for example, values of changes in the three axes of acceleration, values of changes in the three axes of geomagnetism and the like for cases of predefined inclination angles of the center axis C of the fastener **11** with respect to the an initial state of the center axis C of the fastener **11** (e.g., 1 degree, 3 degrees, 5 degrees, 10 degrees).

In addition, at least one standard value (e.g., multiple standard values) for determining (i.e., estimating) a state of the fastener **11** (e.g., a deterioration state of the fastener **11**) is stored in the memory **23**. The standard values are one example of "values set in advance". In the present embodiment, the standard values are set for the three axis gyro **21***c*, for example.

Specifically, at least one standard value (e.g., multiple standard values) for determining (i.e., estimating) a deterioration state of the fastener **11** due to vibrations is stored in the memory **23**. The standard values include, for example, the total amount of vibration in three axes (e.g., the total amount of vibration in each of the three axes) for cases where deterioration of the fastener **11** has advanced to a predefined degree. Here, the standard values relating to vibration may be set based on past statistical data of the fastener **11** in similar equipment, for example. Also, all of the standard values described above can be set or changed by wireless communication from the external apparatus **28** through the wireless module **24** described below.

The detector (e.g., detection circuit) **22** is implemented by a part of circuitry included in the MCU **46**, for example. The detector **22** of the present embodiment detects changes in the orientation of the fastener **11**, and estimates (e.g., determines) the degree of deterioration of the fastener **11**, based on output from the sensor **21**.

In detail, the detector **22** receives output from the sensor **21**. For example, at predefined sampling periods the detector **22** receives a measured value from the acceleration sensor **21***a* relating to the three axes, a measured value from the geomagnetic sensor **21***b* relating to the three axes, and a measured value from the gyro **21***c* relating to the three axes.

In the present disclosure, a "measured value" is a value obtained by measurement. On the other hand, for cases where "value" is described, such as a "value obtained from output of the sensor **21**", the "value" is not limited to a measured value, nor is the "value" limited to a numerical value, as described above. The "value" may also be indicator which indicate an attribute such as High/Low, for example. Further, in the present disclosure, "output" means at least one of an electronic signal output by the sensor **21** based on a detection result of the sensor **21**, and information contained in the electronic signal. "Output" of the sensor **21** as described in the present disclosure can thus be read as a "detection result of the sensor".

The detector **22** detects changes in the orientation of the fastener **11**, and estimates (e.g., determines) the degree of deterioration of the fastener **11**, based on a value obtained from output of the sensor **21**. For example, the detector **22** detects changes in the orientation of the fastener **11**, and estimates (e.g., determines) the degree of deterioration of the fastener **11**, based on a value obtained from output of the sensor **21** and the above-described standard values. In the present disclosure, "based on" means "based at least on". That is, in the present disclosure, "based on a specific basis" includes both cases of "based on" a single specific basis, as well as cases of "based on" another specific basis, as well as the single specific basis.

In the present embodiment, the detector **22** detects changes in the orientation of the fastener **11**, and determines the degree of deterioration of the fastener **11**, by comparing a value obtained from output of the sensor **21** with the standard values. Here, "value obtained from output of the sensor **21**" is, for example, a value obtained by deducting the zero correction value set during initialization from output by the sensor **21** (i.e., amount of change from the zero value). "value obtained from output of the sensor **21**" may also be an actual measured value included in output of the sensor **21**, and may also be a value generated from the output of the sensor **21** by performing a predefined computation process or determination process on the measured value. That is, "a value obtained from output of the sensor" in the present disclosure can thus be read as "a value included in or generated from output of the sensor". For example, when a value obtained from output of the sensor **21** is equal to or greater than a first standard value included in the standard values, the detector **22** detects a state that the rotation (e.g., looseness), inclination, or degree of deterioration of the fastener **11** has advanced to a first state. Further, when a value obtained from output of the sensor **21** is equal to or greater than a second standard value included in the standard values, the second standard value being larger than the first standard value, the detector **22** detects a state that the rotation (e.g., looseness), inclination, or degree of deterioration of the fastener **11** has advanced to a second state. On the other hand, when a value obtained from output of the sensor **21** is less than a first standard value included in the standard values, the detector **22** detects a state that the rotation (e.g., looseness), inclination, or degree of deterioration of the fastener **11** has not advanced to the first state. Further, when a value obtained from output of the sensor **21** is equal to or greater than the first standard value included in the standard values, and less than the second standard value, the detector **22** detects a state that the rotation (e.g., looseness), inclination, or degree of deterioration of the fastener **11** has advanced to the first state but has not advanced to the second state.

In the present embodiment, the detector **22** detects the degree of rotation of the fastener **11** with respect to the fixation object **100** by comparing a value obtained from (i.e., a value included in or generated from) output of the accelerator sensor **21***a* to the standard values set for the acceleration sensor **21***a*. Further, the detector **22** detects the degree of rotation of the fastener **11** with respect to the fixation object **100** by comparing a value obtained from (i.e., a value included in or generated from) output of the geomagnetic sensor **21***b* to the standard values set for the geomagnetic sensor **21***b*. Alternatively, the detector **22** may be instead used to determine only whether or not rotation of the fastener **11** exceeds a predefined standard amount.

In addition, in the present embodiment, the detector **22** detects changes in inclination of the center axis C of the fastener **11** by comparing a value obtained from (i.e., a value included in or generated from) output of the accelerator sensor **21***a* to the standard values set for the acceleration sensor **21***a*. Further, the detector **22** detects changes in inclination of the center axis C of the fastener **11** by comparing a value obtained from (i.e., a value included in or generated from) output of the geomagnetic sensor **21***b* to the standard values set for the geomagnetic sensor **21***b*. Alternatively, the detector **22** may be instead used to detect only whether or not inclination of the center axis C of the fastener **11** exceeds a predefined standard amount.

In addition, in the present embodiment, the detector **22** is used to determine the degree of deterioration of the fastener **11** due to vibration by comparing a value obtained from (i.e., a value included in or generated from) output of the gyro **21***c* to the standard values set for the gyro **21***c*. The detector **22** may be instead used to determine only whether or not the degree of deterioration of the fastener **11** exceeds a predefined standard amount.

The detector **22** transmits detection results relating to changes in the orientation of the fastener **11**, and detection results of the degree of deterioration of the fastener **11**, to the external apparatus **28** described below through the wireless module **24**. For example, the detector **22** transmits detection results relating to rotation of the fastener **11** with respect to the fixation object **100**, and detection results relating to changes in inclination of the center axis C of the fastener **11**, detected based on output of the acceleration sensor **21***a* and the geomagnetic sensor **21***b*, to the external apparatus **28**. Further, the detector **22** transmits detection results relating to the degree of deterioration of the fastener **11** detected based on output of the gyro **21***c* to the external apparatus **28**.

Here, detection operations of the detector described above are not limited to the ones being performed based on the standard values. For example, the detector may instead detect changes in the orientation of the fastener **11**, and be used to determine the degree of deterioration of the fastener, by comparing a new value output from the sensor **21** with a past value output from the sensor **21**. That is, the detector **22** may also detect a state that rotation (e.g., looseness), inclination, or the degree of deterioration of the fastener **11** has advanced when a newly output value obtained from the sensor **21** exceeds a predefined amount compared to a past value obtained from the sensor **21**. On the other hand, the detector **22** may also detect a state that rotation (e.g., looseness), inclination, or the degree of deterioration of the fastener **11** has not advanced when a newly output value obtained from the sensor **21** does not exceed a predefined amount compared to a past value obtained from the sensor **21**.

The wireless module **24** refers to a module configured to at least transmit a signal or signals. The module can be implemented by hardware. The wireless module **24** includes, but is not limited to, circuitry and at least an antenna. For example, the wireless module **24** may include any additional structural element in addition to the circuitry and the antenna. The circuitry may be electrically coupled to the antenna. The circuitry may include, but not limited to, a wireless circuit **31** in FIG. **3**. In FIG. **3**, the wireless module **24** includes the wireless circuit **31** and the antenna **32**. The antenna may be, but not limited to, the antenna **32** in FIG. **3**. The wireless circuit **31** may be connected to the antenna **32**.

The wireless circuit **31** converts signals representing information received from the detector **22** into signals capable of being output from the antenna **32**. The wireless circuit **31** of the present embodiment is a wireless circuit conforming to the standards of, for example, Bluetooth (trademark). However, the wireless circuit **31** is not limited to the example described above. For example, the wireless circuit **31** may conform to communication standards utilized by Zigbee (trademark), Near Field Communication (NFC), or the 920 MHz band.

The antenna **32** is electrically connected to the wireless circuit **31**. The antenna **32** may be a chip antenna, or may be a pattern of conductor on a surface of a circuit board **41** described below. The antenna **32** transmits signals received from the wireless circuit **31** to the external apparatus **28** as a wireless radio wave.

Further, in the present embodiment, identification information (i.e., identifier, e.g., an identification ID) may be assigned to the wireless module **24**. The identification information is one example of identification information capable of distinguishing the fastener **11**, to which the wireless device **1** is mounted, from other fasteners **11**. The wireless module **24** transmits the identification information of the wireless module **24** to the external apparatus **28**. When the wireless module **24** does not have identification information, or when necessary, identification information (i.e., identifier) may also be assigned to the wireless device **1**. In this case, the wireless module **24** may also transmit identification information assigned to the wireless device **1** to the external apparatus **28** as a substitute for the identification information of the wireless module **24**, or in addition to the identification information of the wireless module **24**.

In the present embodiment, the wireless module **24** transmits information from output of the sensor **21**, and the identification information described above, to the external apparatus **28** through the antenna **32** as a wireless radio wave. The wireless module **24** transmits the information and the identification information described above to the external apparatus **28** periodically (e.g., once per 24 hour period). "Information obtained from output of the sensor" may be an actually-measured value included in output from the sensor **21**, and may also be information obtained by performing a predefined computation process, determination process, or the like on the measured value. In the present embodiment, the wireless circuit **31** transmits detection results from the detector **22** as "information obtained from output of the sensor". That is, "information obtained from output of the sensor" in the present disclosure can thus be read as a "information included in or generated from output of the sensor". For example, "detection results from the detector" includes detection results relating to rotation of the fastener **11** with respect to the fixation object **100**, detection results relating to changes in inclination of the center axis C of the fastener **11**, detection results relating to deterioration of the fastener **11**, and the like.

Further, the wireless module **24** receives a radio wave output from the external apparatus **28**. A user of the wireless device **1** can thus make changes to the initialization settings and the standard values stored in the memory **23**, and changes to the timing at which the detection results are sent from the detector **22**, and the like.

Here, the external apparatus (e.g., information processing device) **28** to which the wireless device **1** transmits information may be an electronic device like a tablet terminal, smart phone, or portable computer, and may also be a communications device (e.g., repeater) connected to a network N.

The battery **25** supplies electronic power to the sensor **21**, the detector **22**, the memory **23**, and the wireless circuit **31** through the electric power supply component **26** described below. The battery **25** may be a primary cell battery, and may also be a secondary cell battery. When the battery **25** is a secondary cell battery, an electric power receiver **34** used for wireless electric charging (e.g., an electricity receiving coil) may also be provided to the circuit board **41** described below (refer to FIG. **3**).

The electric power supply component (i.e., electric power circuit component) **26** is electrically connected to the battery **25**, and is also electrically connected to the sensor **21**, the detector **22**, the memory **23**, and the wireless circuit **31**. The electric power supply component **26** is, for example, a low dropout linear regulator (LDO). The electric power supply component **26** converts a voltage supplied from the battery **25** into voltages required by each component **21**, **22**, **23**, and **31**. In the present disclosure, "electric power supply component" is not limited to an LDO, and may also be another component relating to an electric power circuit.

[1-2. Structure of Sensor Unit]

FIG. **3** illustrates a cross-section of the wireless device **1**. As illustrated in FIG. **3**, the wireless device **1** includes the circuit board **41**, the chip component **42**, the electric power supply component **26**, the antenna **32**, a housing **43**, the battery **25**, and a battery protection member **44**.

The circuit board (i.e., board) **41** is formed in a rectangular plate shape, and located outside the fastener **11**. The circuit board **41** is arranged with the head **15** of the fastener **11** in a direction along the center axis C of the fastener **11**. The chip component **42**, the electric power supply component **26**, and the antenna **32** are mounted on a surface of the circuit board **41**, and electrically connected to the circuit board **41**. The chip component **42**, the electric power supply component **26**, and the antenna **32** are located on a side of the circuit board **41** opposite to a side of the circuit board **41** facing the fastener **11** and the battery **25**.

The chip component (e.g., semiconductor component) **42** includes the sensor **21**, the MCU **46**, and the wireless circuit **31** described above. The chip component **42** is a component in which the sensor **21**, the MCU **46**, and the wireless circuit **31** are sealed together using a molding resin **47** (refer to FIG. **4**). Further, the MCU **46** is a semiconductor component including the detector **22** and the memory **33** described above.

The housing **43** is an example of a container, and is exposed to the outside of the wireless device **1**. The housing **43** accommodates the circuit board **41**, the chip component **42**, the electric power supply component **26**, and the antenna **32**. For example, the housing **43** is a molded resin that seals the circuit board **41**, the chip component **42**, the electric power supply component **26**, and the antenna **32** together. That is, the housing **43** is made from a synthetic resin, and allows a wireless signal radio wave to pass. Further, a through hole **43*h*** through which the battery **25** passes is formed in the housing **43**. By passing through the through hole **43*h***, the battery **25** is electrically connected to the circuit board **41**.

The housing **43** is smaller than a diameter of the head **15** of the fastener **11**. In other words, when looking in a direction along the center axis C of the fastener **11**, the housing **43** is within an outline OL (i.e., within an area defined by the side edge) of the head **15** (refer to FIG. **4**). That is, the circuit board **41**, the sensor **21**, the electronic component **26**, the wireless circuit **31**, and the antenna **32** (in other words, the entire sensor unit **12**) are disposed inside the outline OL of the head **15** when viewed in a direction along the center axis C of the fastener **11**.

FIG. **4** is a cross-section of the wireless device **1** illustrated in FIG. **3** taken along a line segment F4-F4 in FIG. **3**. For convenience, the housing **43** is illustrated by a two-dot chain line in FIG. **4**

As illustrated in FIG. **4**, compared to at least a part of the electric power supply component **26**, the chip component **42** (e.g., sensor **21**) is disposed closer to the center axis C of the fastener **11**. Further, taken from another viewpoint, at least a part of the chip component **42** is disposed in a position overlapping the center axis C of the fastener **11**. Stated further, of the chip component **42**, the sensor **21** is disposed in a location overlapping the center axis C of the fastener **11**.

As illustrated in FIG. **3**, the fastener **11** of the present embodiment includes the mounting hole **18** that accommodates at least a part of the sensor unit **12**. The mounting hole **18** is an example of a "hole". The mounting hole **18** is formed along the center axis C of the fastener **11**. The mounting hole **18** is formed from the head **15** to the thread body **16** of the fastener **11**. Further, the mounting hole **18** has an opening portion **18*a*** formed in the head **15** of the fastener **11**. The mounting hole **18** can be exposed to the outside of the wireless device **1** through the opening portion **18*a***.

More specifically, the mounting hole **18** includes a first portion **51** and a second portion **52**. The first portion **51** is formed in the head **15** of the fastener **11** and accommodates a part of the housing **43**. As illustrated in FIG. **4**, the housing **43** is a box shape formed in a polygonal shape (e.g., a rectangular shape) here. In other words, the housing **43** includes a first portion **43*a*** at a first distance from the center axis C, and a second portion **43*b*** at a second distance from the center axis C. The second distance is longer than the first distance. The first portion **51** of the mounting hole **18** has a shape corresponding to an outer shape of the housing **43**. The housing **43** is inserted into the first portion **51** of the mounting hole **18**. That is, the first portion **51** of the mounting hole **18** has an edge along the first portion **43*a*** of the housing **43**, and an edge along the second portion **43*b*** of the housing **43**. The housing **43** thus rotates along with rotation of the fastener **11** when the fastener **11** rotates with respect to the fixation object **100**.

Further, as illustrated in FIG. **3**, the housing **43** has a claw (i.e., catch portion) **43*c*** to be fixed to the fastener **11**. The claw **43*c*** has elasticity, is made from a synthetic resin, for example, and engaged to an engaging portion **11*a*** of the fastener **11**. The housing **43** is relatively easily fixed to the fastener **11** by the claw **43*c*** of the housing **43** being detachably attached to the engaging portion **11*a*** of the fastener **11**.

The second portion **52** of the mounting hole **18** is provided in the head **15** and the thread body **16** of the fastener **11**. An opening surface area of the second portion **52** is smaller compared to an opening surface area of the first portion **51**. The battery **25** of the present embodiment has a cylindrical shape along the center axis C of the fastener **11**. The battery **25** is inserted into the second portion **52** of the mounting hole **18**, and is accommodated in the second portion **52** of the mounting hole **18**.

The battery protection member **44** is provided between the battery **25** and an inner surface (e.g., inner circumferential surface and base surface) of the second portion **52** of the mounting hole **18**. The battery protecting member **44** is a made from a synthetic resin, and has insulating properties (e.g., electric insulating properties). Here, the battery protecting member **44** may also be an insulating film member.

FIG. **5** is a cross-section of the wireless device **1** illustrated in FIG. **3** taken along a line segment F**5**-F**5** in FIG. **3**.

As illustrated in FIG. **5**, the battery protecting member **44** has an outer shape formed in polygonal shape (e.g., a rectangular shape). In other words, the battery protecting member **44** includes a first portion **44*a*** at a first distance from the center axis C, and a second portion **44*b*** at a second distance from the center axis C. The second distance is longer than the first distance. The second portion **52** of the mounting hole **18** has a shape corresponding to an outer shape of the battery protecting member **44**. The battery protecting member **44** is inserted in the second portion **52** of the mounting hole **18**. That is, the second portion **52** of the mounting hole **18** has an edge along the first portion **44*a*** of the battery protecting member **44**, and an edge along the second portion **44***b*. The battery protecting portion **44** thus rotates along with rotation of the fastener **11** when the fastener **11** rotates with respect to the fixation object **100**.

Here, the shapes of the housing **43**, the battery protecting portion **44**, and the mounting hole **18** are not limited to the example described above. For example, the sensor unit **12** may also rotate along with rotation of the fastener **11** by being fixed to the fastener **11** using an adhesive.

The sensor unit **12** is detachably attached to the fastener **11**. That is, the sensor unit **12** is capable of being dismounted from the fastener **11**. For example, when the battery **25** level has gotten low, the sensor unit **12** may be replaced by a new sensor unit **12**.

[2. Detection System]

The detection system (e.g., detection center, information processing system) **2** using the wireless device **1** is described below. FIG. **6** is a block diagram of a system configuration of the detection system **2**.

The detection system **2** of the present embodiment detects a state of the fastener **11**, and a state of the fixation object **100** to which the fastener **11** is mounted, based on information from multiple wireless devices **1**.

As illustrated in FIG. **6**, the detection system **2** acquires information from multiple wireless devices **1** through, for example, the external apparatus (e.g., communication device) **28** and the network N.

More specifically, the detection system **2** includes a device information database (device information DB) **61**, a comparison information database (comparison information DB) **62**, a detector **63**, an output module **64**, and a display screen **65**. The device information DB **61** and the comparison information DB **62** are implemented by a server **66** included in the detection system **2**, for example. Further, the detector **63** and the output module **64** are implemented by information processing device **67** (e.g., additionally more specifically, a circuit board, a processor, and a memory of the information processing device **67**) included in the detection system **2**, for example.

The device information DB (e.g., wireless device information DB and fastener information DB) **61** stores information relating to multiple wireless devices **1** (i.e., multiple fasteners **11**). That is, the wireless device information DB **61** stores setting locations, setting states (e.g., setting orientations) and the like for each wireless device **1**, and associated identification information (e.g., the identification information described above) for each wireless device **1**.

The comparison information DB (e.g., statistical information DB) **62** stores previously acquired information (e.g., statistical data) relating to output from wireless devices **1** in similar installations (e.g., equipment, facilities). That is, the comparison information DB **62** stores output from each wireless device **1** in a similar installation obtained previously, and associated actual states of the fastener **11** of each wireless device **1** (e.g., the degree of looseness, or the degree of deterioration, of the fastener **11**). For example, the comparison DB **62** stores information relating to vibrations acting on the fastener **11** of each wireless device **1**, and associated actual states of the fastener **11** of each wireless device **1** (e.g., the degree of deterioration of the fasteners **11**).

Further, the comparison DB **62** stores previously acquired information output from multiple wireless devices **1** in similar installations, and associated actual states of the fixation object **100** (e.g., the degree of deterioration of the fixation objects **100**).

The detector (e.g., detector circuit) **63** of the present embodiment estimates (e.g., determines) the degree of deterioration of the fastener **11** based on information from each wireless device **1**. For example, the detector **63** receives values obtained from (i.e., included in or generated from) output by the gyro **21***c* of each wireless device **1**. The detector **63** estimates (e.g., determines) the degree of deterioration of the fastener **11** based on values obtained from (i.e., included in or generated from) output of the gyros **21***c* and information stored in the device information DB **61** and the comparison information DB **62**.

Further, the detector **63** estimates (e.g., determines) an overall state of the fixation object **100** to which multiple fasteners **11** are mounted (e.g., the overall state of deterioration of the fixation object **100**) based on values obtained from (i.e., included in or generated from) output of the sensors **21** of each wireless device **1** and information stored in the device information DB **61** and the comparison information DB **62**.

Here, each wireless device **1** need not have the detector **22** in the sensor unit **12**. In this case, the wireless device **1** may transmit the output from the sensor **21**, as is, to the detection system **2** through the external apparatus (e.g., communications device) **28**. Further, the detector **63** of the detection system **2** may also have substantially the same function as the detector **22** of the sensor unit **12** described above. That is, the detector **63** of the detection system **2** may also detect changes in the orientation of the fastener **11** based on values obtained from (i.e., included in or generated from) the output of at least one of the acceleration sensor **21***a* and the geomagnetic sensor **21***b*. That is, the detector **63** of the detection system **2** may also detect changes in rotation of the fastener **11** with respect to the fixation object **100** and inclination of the center axis C of the fastener **11**.

The output module (e.g., output circuit) **64** receives, from the detector **63**, information detected by the detector **63**. The output module **64** displays information related to the detection result of the detector **63** on the display screen **65**.

The detection system **2** is not limited to a system that acquires information from the wireless device **1** through the network N. The detection system **2** may also be in the external apparatus **28**, which is an electronic apparatus (e.g., information processing device) such as a smart phone, tablet terminal, or portable computer, for example.

A configuration described above may lead to reduction of inspections of the fastener **11**. That is, the wireless device **1** of the present embodiment includes the sensor **21**, antenna **22**, and the wireless circuit **31**. The sensor **21** is coupled with the fastener **11**, and generates an output based on a change in the orientation of the fastener **11**. The wireless circuit **31** transmits information included in or generated from the output of the sensor **21** outside the wireless device **1** through the antenna **32**. That is, the wireless circuit **31** transmits at least the output of the sensor **21** and a signal which is generated based on the output of the sensor **21**.

According to such a configuration, when a change in the orientation develops in a certain fastener **11** which is included multiple fasteners **11**, the fastener **11** in which the change in the orientation has developed may be easily identified based on information from the sensor **21** via wireless communication. It may thus become unnecessary to perform inspection (i.e., total inspection at installation sites by inspectors) of all fasteners **11**. Alternatively, the inspection frequency of the fasteners **11** may be reduced.

Further, according to the above configuration, wireless communication function achieved by the wireless device **1** and detection function achieved by the sensor unit **12** can be added to the fastener **11**. Further, special work for installment of the sensor unit **12** to the fixation object **100** is not required.

In the present embodiment, the sensor **21** generates an output based on a change in direction of force acting on the sensor **21**, where the change in direction of the force is caused by a change in the orientation of the fastener **11**. According to such a configuration, a change in the orientation of the fastener **11** can be detected using a relatively small sensor compared to a sensor that is provided for directly detecting a change in the orientation (e.g., rotation) of the fastener **11**. According to such a configuration, the wireless device **1** may thus be miniaturized and reductions in cost may be achieved. Here, "directly" detecting a change in the orientation means, for example, detecting a change in the orientation of the fastener **11** according to actual mechanical changes (i.e., actual rotation or movement) between a first member mounted on an outside circumference surface of the head **15** of the fastener **1**, which moves according to changes (e.g., rotation) in the orientation of the fastener **11**, and a second member fixed to the fixation object **100**. On the other hand, the sensor **21** of the present embodiment detects a change in the orientation of the fastener **11** by detecting a change in the direction of force acting on the fastener **11** according to a change in the orientation of the fastener **11**. According to such a configuration, it becomes possible to detect a change in the orientation of the fastener **11** by using a relatively small size chip mounted in a circuit board. The wireless device **1** may thus be miniaturized, and cost reduction may be achieved.

In the present embodiment, the sensor **21** generates an output based on a change in direction of force acting on the sensor **21** due to rotation of the fastener **11**. According to such a configuration, loosening of the fastener **11** can be detected by detecting a change in direction of a force acting on the sensor **21** due to rotation of the fastener **11**.

In the present embodiment, the sensor **21** generates an output based on at least one of a change in direction of a gravitational force acting on the sensor **21** and a change in direction of a force acting on the sensor **21** caused by geomagnetism. The direction of a force due to gravity or geomagnetism easily and certainly changes along with rotation of the fastener **11**. Accordingly, a state of the fastener **11** may be easily and precisely detected by detecting at least one of a change in direction of gravity and a change in direction of a force caused by geomagnetism.

In the present embodiment, the sensor **21** includes at least one of the acceleration sensor **21***a* and the geomagnetic sensor **21***b*. According to such a configuration, at least one of a change in direction of the gravitational force acting on the sensor **21** and a change in direction of a force acting on the sensor **21** caused by geomagnetism can be detected.

In the present embodiment, at least one of the acceleration sensor **21***a* and the geomagnetic sensor **21***b* generates an output based on rotation of the fastener **11**. According to such a configuration, loosening of the fastener **11** may easily be detected based on information from the sensor **21**.

In the present embodiment, at least one of the accelerator sensor **21***a* and the geomagnetic sensor **21***b* rotates integrally with the fastener **11**. According to such a configuration, rotation of the fastener **11** may be more accurately detected by the acceleration sensor **21***a* and the geomagnetic sensor **21***b*.

When the center axis C of the fastener **11** is along the direction of gravity, rotation around the center axis C of the fastener **11** may not be detected by using only output from the acceleration sensor **21***a*. Similarly, rotation around the

center axis C of the fastener **11** may not be detected by only using output of the geomagnetic sensor **21***b*, depending upon the orientation of the fastener **11** installation.

In the present embodiment, the sensor **21** includes both the acceleration sensor **21***a* and the geomagnetic sensor **21***b*. According to such a configuration, since both the output of the acceleration sensor **21***a* and the output of the geomagnetic sensor **21***b* are used, a change in the orientation of the fastener **11** (e.g., rotation of the fastener **11**) may be detected with high accuracy.

In the present embodiment, the sensor **21** includes a vibration detection sensor (e.g., the gyro **21***c*) for detecting a vibration of the fastener **11**. According to such a configuration, the degree of deterioration of the fastener **11** due to vibrations may be determined based on information from the sensor **21**.

In the present embodiment, the wireless device **1** includes the detector **22** that detects a change in the orientation of the fastener **11** by comparing a value included in or generated from output of at least one of the acceleration sensor **21***a* and the geomagnetic sensor **21***b* with a value set in advance. The wireless circuit **31** transmits information form the detector **22**. According to such a configuration, the external apparatus **28** (or the detection system **2**) can receive information relating to whether or not there is a change in the orientation of the fastener **11**, and a degree of the orientation change, from the wireless device **1**. The functions necessary for the external apparatus **28** (or for the detection system **2**) may thus be reduced. A wireless device **1** with more convenience may thus be provided.

In the present embodiment, the fastener **11** is a bolt including the head **15** and the thread body **16**. The sensor **21**, the wireless circuit **31**, and the antenna **32** are disposed within an area defined by the side edge of the head **15** when viewed in a direction along the center axis C of the thread body **16**. According to such a configuration, the external shape of the fastener **11** does not easily increase, even when the sensor unit **12** is mounted to the fastener **11**. Miniaturization of the wireless device **1** may thus be achieved. By using this kind of wireless device **1**, there are fewer limitations on locations where the fastener **11** may be disposed.

In the present embodiment, the wireless device **1** includes the electric power supply component **26** which is electrically connected to the sensor **21**. A farthest portion of the sensor **21** from the center axis C of the fastener **11** is closer to the center axis C than a farthest portion of the electric power supply component **26** from the center axis C. According to such a configuration, the sensor **21** is disposed near a center portion of the fastener **11**. If the sensor **21** is disposed near a center portion of the fastener **11**, the sensor **21** easily detects vibrations, no matter which direction the vibrations are input from, for example. The detection accuracy of the sensor **21** may thus be increased.

In the present embodiment, the wireless device **1** includes the chip component **42**. The chip component includes the sensor **21**. At least a part of the chip component **42** is disposed in a location overlapping the center axis C of the thread body **16** when viewed in a direction along the center axis C of the thread body **16**. According to such a configuration, the sensor **21** is disposed additionally closer to a center portion of the fastener **11**. If the sensor **21** is disposed additionally closer to a center portion of the fastener **11**, the sensor **21** easily detects vibrations, no matter which direction the vibrations are input from, for example. The detection accuracy of the sensor **21** may thus be increased.

Further, when the acceleration sensor **21***a* and the geomagnetic sensor **21***b* are in a location apart from the center axis C of the fastener **11**, it may be necessary to correct output from the acceleration sensor **21***a* and the geomagnetic sensor **21***b*. However, if the sensor **21** is disposed near the center axis C of the fastener **11** like in the present embodiment, the corrections described above may be omitted. A wireless device **1** having additionally high convenience may thus be provided.

In the present embodiment, the wireless device **1** includes the sensor unit **12**. The sensor unit **12** includes the sensor **21**, the wireless circuit **31**, and the antenna **32**. The mounting hole **18** that accommodates at least a part of the sensor unit **12** is formed in the fastener **11**. According to such a configuration, miniaturization of the wireless device **1** may be achieved.

In the present embodiment, the fastener **11** is a bolt including the head **15** and the thread body **16**. The head **15** has the mounting hole **18**. According to such a configuration, a part of the sensor unit **12** may be accommodated in the head **15**, which is larger in size compared to the thread body **16**. Further miniaturization of the wireless device **1** may thus be achieved.

In the present embodiment, the sensor unit **12** includes the battery **25** for supplying an electric power to the sensor **21**. The fastener **11** has the mounting hole **18** which penetrates the head **15** and reaches the thread body **16**, and accommodates the battery **25**. According to such a configuration, the sensor unit **12** may be accommodated by the relatively large mounting hole **18** across the head **15** and the thread body **16**. Further miniaturization of the wireless device **1** may thus be achieved. Further, seen from another viewpoint, according to the configuration described above, a relatively large battery **25** may be disposed while also achieving miniaturization of the wireless device **1**. By increasing the capacity of the battery **25**, the battery life of the wireless device **1** may be lengthened.

In the present embodiment, the detection system **2** includes the detector **63** and the output module **64**. The detector **63** detects a change in the orientation of the fastener **11** based on information from the wireless device **1**. The output module **64** is configured to output information related to the change detected by the detector **63** to the display screen **65**.

According to such a configuration, when a change in the orientation of a certain fastener **11** has developed among multiple fasteners **11**, the fastener **11** in which a change in the orientation has developed may be easily identified based on information from the wireless device **1**. It this becomes unnecessary to perform inspection of all fasteners **11**. Alternatively, the frequency at which the inspection of all fasteners **11** is performed may be reduced.

Further, in the present embodiment, the detector **63** of the detection system **2** determines a state of the fastener **11** (e.g., the degree of deterioration of the fastener **11**) based on information from the wireless device **1** (e.g., the gyro **21***c*). According to such a configuration, fasteners **11** having a relatively large degree of deterioration may be identified, and individual inspections may be performed, without performing inspection of all fasteners **11**. The burden of inspections may thus be reduced.

Further, the detector **63** of the detection system **2** determines a state of the fixation object **100** to which multiple fasteners **11** are mounted (e.g., the degree of deterioration of the fixation object **100**) based on information from the output of the sensors **21** of multiple wireless devices **11**. According to such a configuration, the state of the fixation object **100** may be understood based on information sent wirelessly from multiple wireless devices **1**. The frequency of inspections of the fixation object **100** may be reduced, for example, and the burden of inspections may be lightened.

Several modification examples of the first embodiment are described next. It is also possible to apply each of the modification examples explained below to a second embodiment described below.

FIG. **7** is a perspective view of the wireless device **1** according to a first modification example. As illustrated in FIG. **7**, in the present modification example, the housing **43** of the sensor unit **12** includes a groove **71** into which the tip of a tool like a screw driver is capable of being inserted. The groove **71** may be a flat blade groove or a cross slot groove. According to such a configuration, work to mount the wireless device **1** to the fixation object **100** may be easily performed. Further, according to such a configuration, the sensor unit **12** may be easily mounted in a variety of fasteners **11**, not only bolts.

FIG. **8** is a perspective view of the wireless device **1** according to a second modification example. As illustrated in FIG. **8**, in the present modification example, a lid **75** is mounted to the head **15** of the fastener **11**. The lid **75** covers the sensor unit **12** from a side opposite to the thread body **16**. The lid **75** includes, for example, a first member **75***a* and a second member **75***b*. The first member **75***a* and the second member **75***b* are each capable of being opened and closed with respect to the head **15** of the fastener **11** by way of, for example, a hinge **76**. By opening the first member **75***a* and the second member **75***b* with respect to the head **15**, it becomes possible to remove the sensor unit **12** from the fastener **11**. The groove **71**, into which the tip of a tool like a screw driver is capable of being inserted, is formed in the lid **75**. The groove **71** may be a flat blade groove or a cross slot groove. According to such a configuration, work to mount the wireless device **1** to the fixation object **100** may be easily performed, similar to the first modified example. Further, according to such a configuration, the sensor unit **12** may be easily mounted in a variety of fasteners **11**, not only bolts.

FIG. **9** is a cross-section of the wireless device **1** according to a third modification example. As illustrated in FIG. **9**, the fastener **11** of the present modification example is made from synthetic resin. Processing is relatively easy when the fastener **11** is made from synthetic resin, and a complex shape fastener **11** may thus be employed. Further, when made from synthetic resin, the fastener does not oxidize like metal, and therefore it is possible to use the fastener **11** for a long period of time in often wet environments, high humidity environments, and environments exposed to wind and rain. In addition, when made from synthetic resin, the fastener **11** is lighter compared to a fastener made of metal. The weight of the fixation object **100** may thus be decreased. Further, when made from synthetic resin, the fastener **11** may also be applied to locations where radio disturbances and other defects occurs when a fastener made from metal is employed.

On the other hand, deterioration advances due to ultraviolet light for a fastener made from synthetic resin.

The sensor **21** of the present modification example includes an ultraviolet light sensor **81**. The housing **81** includes a window **82** that exposes the ultraviolet light sensor **81** to the outside of the housing **43**. The window **82** allows ultraviolet light included in sunlight to be incident to the ultraviolet light sensor **81**. The ultraviolet light sensor **81** measures the intensity of ultraviolet light bathing the fastener **11**. The ultraviolet sensor **81** outputs ultraviolet light measurement results to the detector **22**. The detector **22** determines the degree of deterioration of the fastener **11** due to ultraviolet light by comparing the value based on the output of the ultraviolet sensor **81** with standard values stored in the memory **23** corresponding to the ultraviolet sensor **81**. The wireless circuit **31** transmits the degree of deterioration of the fastener **11** due to ultraviolet light estimated by the detector **22** to the external apparatus **28**.

Further, instead of the above description, information relating to the amount of ultraviolet light received by each wireless device **1** in similar installations, and actual states of the fasteners **11** in each of the wireless devices **1** (e.g., degrees of deterioration of the fasteners **11**) may be stored in the comparison information DB **62** of the detection system **2** of the present modified example. The detector **63** of the detection system **2** may also determine the state of the fastener **11** (e.g., the degree of deterioration of the fastener **11**) based on a value obtained from (i.e., included in or generated from) output of the ultraviolet sensor **81** from the wireless device **1**, and information in the comparison information DB **62**.

According to the above configuration, deterioration of the synthetic resin made fastener **11** may be estimated well, with high accuracy. The detection accuracy of the wireless device **1** may thus be increased.

Second Embodiment

The wireless device **1** of a second embodiment is described with reference to FIG. **10** and FIG. **11**. Differing from the first embodiment described above, the wireless device **1** of the present embodiment is capable of being detachably attached to a general purpose fastener (i.e., a general fastener on the market) **11**. The other configurations of the wireless device **1** according to the second embodiment are similar to those of the first embodiment described above. Further, the detection system **2** utilizing the wireless device **1** of the present embodiment is similar to the detector system **2** of the first embodiment described above.

FIG. **10** illustrates a cross-section of the wireless device **1** according to the present embodiment. As illustrated in FIG. **10**, the wireless device **1** of the present embodiment is mounted to, for example, a general purpose bolt (e.g., a general purpose hex head bolt). The wireless device **1** includes the sensor unit **12**, and a mounting member (attachment member) **90** capable of detachably attaching the sensor unit **12** to the fastener **11**.

The sensor unit **12** of the present embodiment is formed in a polygonal shape (e.g., a hexagonal shape) substantially the same as the head **15** of the fastener **11**. The sensor unit **12** overlaps the head **15** of the fastener **11** in a direction along the center axis C of the fastener **11**.

In the present embodiment, the battery **25** is accommodated in the housing **43**. The battery **25** has a flat cylindrical shape, and has an external shape smaller than the circuit board **41**, for example. The battery **25** overlaps the circuit board **41** on a side opposite the chip component **42** and the like.

In the present embodiment, the antenna **32** is disposed nearer to the center axis C of the fastener **11** than the chip component **42** and the electric power supply component **26**. At least a part of the antenna **32** is disposed in a location overlapping the center axis C of the fastener **11** when seen in a direction along the center axis C of the fastener **11**. According to such a configuration, the antenna **32** may be separated from the mounting member **90** made from metal and described below. The communication properties of the antenna may thus be reliably maintained.

The mounting member **90** is, for example, a metallic cap used for fixing. The mounting member **90** has a first portion **91**, a second portion **92**, and a third portion **93**.

FIG. **11** illustrates a planar diagram of the wireless device **1** according to the present embodiment. As illustrated in FIG. **10** and FIG. **11**, the first portion **91** of the mounting member **90** is a portion that covers the head **15** of the fastener **11** and a side surface of the sensor unit **12**. The first portion **91** of the mounting member **90** is formed in a polygonal (e.g., a hexagonal) cylindrical shape following an outer shape of the head **15** of the fastener **11** and an outside shape of the sensor unit **12**. The first portion **91** of the mounting member **90** rotates along with rotation of the fastener **11**. The first portion **91** of the mounting member **90** thus causes the sensor unit **12** to rotate corresponding to rotation of the fastener **11**. Further, the first portion **91** of the mounting member **90** includes an opening portion **91***a* that passes through to the sensor unit **12** toward inside of the mounting member **90**. The sensor unit **12** is accommodated inside the mounting member **90** by being inserted into the opening portion **91***a*.

As illustrated in FIG. **10**, the second portion **92** of the mounting portion **90** faces the head **15** of the fastener **11** from a side opposite to that of the sensor unit **12**. In other words, the second portion **92** of the mounting member **90** sandwiches and holds the fastener **11** between the second portion **92** and the sensor unit **12**. The fastener **11** thus cannot come out from the mounting member **90**. The second portion **92** of the mounting member **90** includes a through hole **92***h* that passes through to the thread body **16** of the fastener **11**. The thread body **16** of the fastener **11** passes through the through hole **92***h*, protruding out to the outside of the mounting member **90**.

The third portion **93** of the mounting member **90** is a claw for fixing the sensor unit **12**. As illustrated in FIG. **11**, the third portion **93** is provided in a part of a peripheral end of the first portion **91**. As illustrated in FIG. **10**, the third portion **93** of the mounting member **90** faces a peripheral portion of the sensor unit **12** from a side opposite to that of the head **15** of the fastener **11**, and supports the sensor unit **12**. In other words, the head **15** of the fastener **11** and the sensor unit **12** are sandwiched and supported between the second portion **92** and the third portion **93** of the mounting member **90**. The sensor unit **12** thus should not be disengaged from the mounting member **90**.

A method of mounting the mounting member **90** and the sensor unit **12** to the fastener **11** is as described below. First, the fastener **11** is inserted into the inside of the mounting member **90**, and the thread body **16** of the fastener **11** is passed through the through hole **92***h* of the mounting member **90**. Next, the sensor unit **12** is inserted into the inside of the mounting member **90**. That is, the sensor unit **12** is inserted between the head **15** of the fastener **11** and the third portion **93**. The fastener **11** and the sensor **12** are thus mounted to the mounting member **90**. On the other hand, by performing the procedures described above in reverse order, the sensor unit **12** and the mounting member **90** can be dismounted from the fastener **11**.

According to such a configuration, the burden of inspections of the fastener **11** may be lightened, similar to the first embodiment described above.

Further, in the present embodiment, the wireless device **1** includes the mounting member **90**. The mounting member **90** is configured to detachably attach the sensor **21**, the wireless circuit **31**, and the antenna **32** to the fastener **11**. According to such a configuration, the wireless device **1** can be coupled to a general purpose fastener **11**. A wireless device **1** having a very high convenience may thus be provided.

The first embodiment, the second embodiment, and modification examples thereof, are described above. However, configurations are not limited to the ones described above. For example, the sensor unit **12** may also have a metal portion, and may also be coupled to the fastener **11** by welding or the like.

Further, the fastener **11**, on which the sensor unit **12** is mounted, is not limited to being fixed using a bolt or screw. The fastener **11** to which the sensor unit **12** is coupled may be a nut. By using this kind of configuration, loosening of the nut or the like can be detected. Further, the fastener **11** on which the sensor unit **12** is coupled may also be a fastener component not having a screw portion, for example, such as a fastener like a rivet. In this kind of case as well, the burden of inspecting the fasteners may be reduced by detecting and transmitting the state of the fastener **11** using the sensor unit **12**.

Further, processors that process information (the detection portion **22** of the sensor unit **12** of the wireless device **1**, the detector **63** and the output module **64** of the detection system **2**, and the like) may also be implemented by a processor such as a CPU or the like running a program. The program may be stored in the memory **23** in the MCU **46**, or in memory included in the detection system **2**. The processors described above may also be implemented by hardware such as an LSI (large scale integration) or an ASIC (application specific integrated circuit) including functions similar to a program run by a processor. The processors described above may also be implemented by a combination of hardware and a processor such as a CPU or the like running a program.

In accordance with at least one embodiment described above, a wireless device of an embodiment includes a sensor, an antenna, and a wireless circuit. The sensor is coupled with a fastener and configured to generate an output based on a change in the orientation of a fastener. The wireless circuit is configured to transmit at least one of the output and a signal which is generated based on the output outside the wireless device through the antenna. According to such a configuration, the burden of inspecting the fastener may be lightened.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms: furthermore various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention.

What is claimed is:

1. A fastener having threads, comprising:
a main body including a head portion and a thread portion having the threads;
a sensor mounted on the main body and configured to generate a signal corresponding to a current state of the fastener;
a nonvolatile semiconductor memory in which a reference value relating to a standard state of the fastener is stored;
a detection circuit configured to determine a degree of deterioration of the fastener based on differences between the current state and the standard state; and
a wireless module mounted on the main body and configured to transmit data indicating the degree of deterioration through a wireless signal.

2. The fastener according to claim **1**, wherein the sensor includes at least one of an acceleration sensor and a geomagnetic sensor.

3. The fastener according to claim **2**, wherein the sensor further includes a vibration sensor.

4. The fastener according to claim **1**, wherein the detection circuit is configured to determine a rotational position of the fastener based on the signal.

5. The fastener according to claim **1**, further comprising:
a battery module mounted on the main body and configured to supply power to the wireless module.

6. The fastener according to claim **5**, wherein
the sensor, the wireless module, and the battery are formed as a package, and the package is mounted on the main body.

7. The fastener according to claim **6**, wherein
the main body includes an inner space formed through the head portion into an interior part of the thread portion, and the battery is disposed in the inner space.

8. The fastener according to claim **7**, wherein
the sensor and the wireless module are disposed on a substrate, and
the battery faces a side of the substrate opposite to the side on which the sensor and the wireless module are disposed.

9. The fastener according to claim **6**, wherein
the package includes a resin enclosure in which the sensor, the wireless module, and the battery are enclosed.

10. The fastener according to claim **9**, wherein
the resin enclosure includes an engaging portion engaged with an engaging portion of the main body.

11. The fastener according to claim **9**, wherein
a cross-sectional peripheral shape of the resin enclosure in a direction perpendicular to a center axis of the fastener is a polygonal shape.

12. The fastener according to claim **1**, wherein
the sensor is formed in a chip, and a center axis of the fastener passes through the chip.

13. The fastener according to claim **1**, wherein
the reference value is a value that is obtained from a signal previously generated by the sensor.

14. The fastener according to claim **1**, wherein
the wireless module is configured to periodically transmit the data indicating the degree of deterioration.

15. A wireless device attachable to a head of a fastener having threads, comprising:
an enclosure;
a sensor within the enclosure and configured to generate a signal corresponding to a current state of the fastener when the wireless device is attached to the fastener;
a nonvolatile semiconductor memory that is disposed in the enclosure and in which a reference value relating to a standard state of the fastener is stored;
a detection circuit configured to determine a degree of deterioration of the fastener based on differences between the current state and the standard state; and
a wireless module within the enclosure and configured to transmit data indicating the degree of deterioration through a wireless signal.

16. The wireless device according to claim **15**, further comprising:

an attachment member having an engaging portion that is engageable with the head of the fastener.

17. The wireless device according to claim **15**, wherein the sensor includes at least one of an acceleration sensor and a geomagnetic sensor.

18. The wireless device according to claim **17**, wherein the detection circuit is configured to determine a rotational position of the fastener based on the signal.

19. The wireless device according to claim **17**, further comprising:

a battery module within the enclosure and configured to supply power to the wireless module.

20. A system for presenting data indicating a degree of deterioration of a fastener used in a structure, comprising:

a fastener including a main body including a head portion and a thread portion having the threads, a sensor coupled to the main body and configured to generate a signal corresponding to a current state of the fastener, a nonvolatile semiconductor memory that is coupled to the main body and in which a reference value relating to a standard state is stored, a detection circuit coupled to determine the degree of deterioration of the fastener based on differences between the current state and the standard state, and a wireless module coupled to the main body and configured to transmit data indicating the degree of deterioration through a wireless signal; and;

a detection center that receives the data transmitted through the wireless signal over a network, and displays the data on a display.

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